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SYSTEM AND METHOD FOR SECURE DOWNLOAD OF WAVEFORMS TO SIGNAL GENERATORS

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BACKGROUND OF THE INVENTION

Technical Field of the Invention

The present invention relates generally to signal generators, and specifically to download of waveforms to signal generators.

Description of Related Art

Signal generation test instruments are utilized in the wireless telecommunications industry to aid in the measurement of the quality of signals transmitted and received over wireless transceiver equipment. A signal generation test instrument includes an RF signal generator that is modulated by a waveform generator. The waveform generator uses a composite modulation technique to encode information in both the amplitude and phase of the modulated signal. Specifically, the waveform generator generates digital samples corresponding to the base-band I (in-phase) and Q (quadrature-phase) components. A set of numerical value pairs (I and Q) of the digital samples that are converted into analog form constitutes the waveform. Since the waveform and signal generation test instrument are specifically calibrated and produce a known signal, the signal generation test instrument can use the waveform to perform measurements on the wireless equipment.

Different types of composite modulation techniques are used for different types of communications formats, such as, Code Division Multiple Access (CDMA) and Time Division

Multiple Access (TDMA). Therefore, instead of using a different signal generation test instrument for each modulation technique, computer-generated waveforms can be downloaded to a generic signal generation test instrument that is capable of transmitting any type of waveform. For example, the generic signal generation test instrument (hereinafter referred to as a signal generator) can be customized to transmit any type of waveform by taking downloaded I and Q values, converting the I and Q values into analog signals through the use of a digital-to-analog converter and using the analog signals to modulate a carrier (i.e., "play" the waveform).

A user can access signal generation software stored on a computer, and configure one or more waveforms for one or more communications formats. The signal generation software includes a different application for each type of communications format. In addition, each signal generator includes one or more "licensing keys", each being associated with a different application. These licensing keys are purchased from the signal generator provider, and prevent unauthorized use of the software. Upon creation of a particular waveform, the signal generation software within the computer checks the signal generator connected to the computer for the appropriate key prior to downloading the waveform to the signal generator.

The waveforms themselves are not stored on the computer containing the signal generation software or in any other location other than the specific signal generator equipment that the waveform was created for, in order to prevent unauthorized equipment from utilizing the waveforms without purchasing a key. However, by requiring the waveforms be stored directly on the signal generator, many test customers who utilize automatic test equipment

systems are not able to implement an automated signal generation solution.

Automatic test equipment (ATE) systems are software-driven, meaning that there is no user-interaction involved. Therefore, ATE systems do not allow a user to manually create a waveform on a computer and download that waveform directly to a signal generator connected to the computer. Instead, ATE systems include software for instructing a signal generator to generate a specific waveform. Therefore, what is needed is a mechanism for storing waveforms on the computer, while maintaining security of the waveforms, in order to provide an ATE solution.

SUMMARY OF THE INVENTION

The present invention provides a system and method for storing waveforms on a computer, while ensuring that the waveforms are only used on a signal generator fitted with the correct licensing keys. The system includes one or more signal generation applications for calculating one or more waveforms. Each waveform can be stored on a computer by bundling the waveform and a code that includes license information into a single file. Upon receiving a request for the file, a download application associated with the signal generator retrieves the file and compares one or more keys stored within the signal generator with the code to determine whether the signal generator is allowed to download the waveform.

In some embodiments, the file is encrypted before being stored on the computer, and the download application decrypts the file prior to checking the code. In further embodiments, the file also includes signal generator settings. The download application uses the signal

generator settings to configure the signal generator for the waveform.

Advantageously, the download application enables the waveforms to be controlled by the customer's Automatic Test Equipment (ATE) system, while maintaining security of the waveforms. In addition, the download application can check for any number of different licensing keys, which enables one application to work with all of the different signal generation applications (i.e., different types of modulation techniques). Therefore, an end-user or ATE system need only learn how to interface with one download application in order to download any type of waveform. Furthermore, the invention provides embodiments with other features and advantages in addition to or in lieu of those discussed above. Many of these features and advantages are apparent from the description below with reference to the following drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The disclosed invention will be described with reference to the accompanying drawings, which show important sample embodiments of the invention and which are incorporated in the specification hereof by reference, wherein:

FIG. 1 is a block diagram of the exemplary components of a computer capable of storing and downloading one or more files containing created waveforms;

FIG. 2 is an exemplary logical block diagram of the signal generation application shown in FIG. 1;

FIG. 3 illustrates the main components of the stored files;

FIG. 4 is a flow chart illustrating the exemplary steps for creating and storing the

waveforms;

FIG. 5 is an exemplary logical block diagram of the download application shown in FIG. 1;

FIG. 6 is a flow chart illustrating the exemplary steps for downloading the stored waveforms;

FIG. 7 illustrates the use of automatic test equipment to download a waveform to a signal generator;

FIG. 8 illustrates the ability to download the waveform to a signal generator via the Internet;

FIG. 9 illustrates remote storage of the files;

FIG. 10 illustrates remote automatic test equipment control of the download application; and

FIG. 11 illustrates remote automatic test equipment control of the download of files from multiple storage facilities to multiple download applications and multiple signal generators.

DETAILED DESCRIPTION OF THE EXEMPLARY EMBODIMENTS OF THE INVENTION

The numerous innovative teachings of the present application will be described with particular reference to the exemplary embodiments. However, it should be understood that these embodiments provide only a few examples of the many advantageous uses of the

innovative teachings herein. In general, statements made in the specification do not necessarily delimit any of the various claimed inventions. Moreover, some statements may apply to some inventive features, but not to others.

FIG. 1 is a block diagram of a computer 100 having one or more signal generation applications 120 and a download application 150 therein. The computer 100 can be a personal computer, server or other type of programmable processing device. The signal generation application(s) 120 and download application 150 are tangibly embodied in a computer-readable medium, e.g., a ZIP® drive, floppy disk, hard drive, CD-ROM, non-volatile memory device, tape or any other type of data storage device. The signal generation applications 120 are each associated with a different communications format, e.g., CDMA, TDMA, etc. Each waveform created using one of the signal generation applications 120 is stored as a file 140 within a storage media 130 that is computer-readable or otherwise accessible, such as a memory. The memory 130 may be any memory type, such as, for example, RAM, ROM, EPROM, EEPROM, HDD or FDD, implemented on any data storage device.

The signal generation applications 120 and files 140 can be included on the same computer 100 as the download application 150, or can be stored on a separate computer or a server (not shown). For example, the signal generation applications 120 can be stored on a web server (not shown) and the created files 140 can be downloaded from the web server to the computer 100 storing the download application 150 or to a different computer (not shown) that is accessible by the download application 150 directly or via a data network (e.g., Internet or local area network).

The download application 150 accesses the memory 130 to retrieve one or more files 140 from memory 130 in order to download the waveforms associated with those files 140. A Central Processing Unit (CPU) 110 controls the creation of waveforms by the signal generation applications 120, the storage of files 140 within the memory 130 and the download of waveforms by the download application 150. The CPU 110 may be any microprocessor or microcontroller configured to load and run the signal generation applications 120 and download application 150 and access the memory 130.

Referring now to FIG. 2, in order to store the waveforms on the computer, while maintaining security of the waveforms from unauthorized users, the signal generation application 120 includes a code 125. Each signal generation application 120 has a unique code 125 (e.g., licensing key) associated with it. The licensing key is used to allow only those customers who have purchased the licensing key for their signal generators to download waveforms created by the signal generation application 120.

The signal generation application 120 is connected to an input device 200 controlled by a user. The input device 200 is, for example, one or more of a keyboard, mouse, voice command software, touch screen, wireless device (for remote control or access via a wireless network) or remote input system (for access via a data network or another computer). The input device 200 connects to an Application Program Interface (API) 121 within the signal generation application 120 to select or enter various parameters 128 related to the signal generator settings and the characteristics of the desired waveform via a graphical user interface provided by the API 121. The API 121 accesses pre-configured signal generator

settings 122 and provides the pre-configured signal generator settings 122 and various input parameters 128 to waveform calculation logic 123, which calculates the parameters of the desired waveform based on the input parameters 128 and pre-configured signal generator settings 122. It should be understood that the term "logic" herein refers to the hardware, software and/or firmware required to perform the functions of the logic.

Bundling logic 124 collects and bundles the calculated waveform 160, code 125 for the signal generation application 120 and any signal generator settings 162 to create a file 140 for the waveform 160, as shown in FIG. 3. The file typically also has a header section 168 identifying the format version of the file itself. In some embodiments, the code 125 can be included as part of the header 168 for the file 140. Referring again to FIG. 2, the bundled file 140 is passed to encryption logic 126 for encryption of the file 140. The encryption logic 126 can use any encryption algorithm (e.g., bit scrambling) to encrypt the file 140. Although a keyed encryption algorithm may be used, it is not necessary due to the proprietary nature of the encryption algorithm (i.e., no outside sources have a need to access the files 140). The encrypted files 140 containing the calculated waveforms are passed to the memory (shown in FIG. 1) for storage via a File input/output (I/O) 127.

FIG. 4 illustrates the exemplary steps for creating and storing the waveforms. Initially, a user requests that one of the signal generation applications be loaded and run (step 400). Thereafter, the selected signal generation application solicits various parameters related to signal generator settings and the waveform from the user (step 410). For example, the user can enter parameters into fields provided by the signal generation application. Alternatively,

the user can select from one or more pre-configured parameters, such as pre-configured signal generator settings. Based on the parameters provided by the user, the waveform is calculated (step 420).

If the user does not select to save the calculated waveform (step 430), the waveform is discarded (step 440). However, if the user does select to save the waveform, the waveform is bundled together with the signal generator settings and code for the selected signal generation application as a file (step 450). Thereafter, the file is encrypted (step 460) and stored on the computer (step 470).

To later download the encrypted file, a download application of the type shown in FIG. 5 is used. The download application 150 is also connected to an input device 300 controlled by a user or another software application. The input device 300 can be, for example, a keyboard, voice command software, touch screen, wireless device (for remote control or access via a wireless network), remote input system (for access via a data network or another computer) or another software application, such as an Automatic Test Equipment (ATE) software application. The input device 300 connects to an Application Program Interface (API) 151 within the download application 150 to request that one or more waveforms be downloaded to one or more signal generators 170.

The API 151 passes the request for a waveform to a File I/O 152, which accesses the memory (shown in FIG. 1) to retrieve the encrypted file 140 containing the requested waveform. The File I/O 152 passes the retrieved encrypted file 140 to decryption logic 153, which decrypts the encrypted file 140 and transmits the decrypted file 140 to de-bundling logic

154. The de-bundling logic 154 separates the file into it's constituent parts: (1) waveform 160; (2) signal generator settings 162; and (3) code 125.

Before downloading the waveform 160 to the signal generator 170, the de-bundling logic 154 passes the code 125 to comparison logic 155, which retrieves one or more keys 165 (i.e., licensing keys) from the signal generator 170 via a signal generator I/O 157. The comparison logic 155 compares the code 125 with the one or more keys 165 to determine whether the code 125 matches any of the keys 165. If the code 125 matches one of the keys 165, the de-bundling logic 155 transmits the signal generator settings 162 to signal generator configuration logic 156, which uses the signal generator settings 162 to configure the signal generator 170 for the waveform 160 via the signal generator I/O 157. The de-bundling logic 154 also transmits the waveform 160 to the signal generator I/O 157 for downloading to the configured signal generator 170.

FIG. 6 illustrates the exemplary steps for downloading stored waveforms to a signal generator. Initially, a user or another software application requests that a waveform be downloaded to a particular signal generator (step 600). Thereafter, the encrypted file containing the requested waveform is retrieved (step 610), decrypted (step 620) and de-bundled (step 630) in order to extract the waveform, signal generator settings and code associated with the waveform.

One or more keys that are stored within the signal generator are retrieved (step 640) and compared with the code to determine whether the code matches any of the keys associated with the signal generator (step 650). If not, the waveform is not downloaded to the

signal generator (step 660). If so, the signal generator is configured using the signal generator settings (step 670) and the waveform is downloaded to the signal generator (step 680).

FIGs. 7-11 illustrate an automatic test equipment (ATE) system including at least an ATE software application 180 for downloading a waveform to a signal generator 170. As shown in FIG. 7, an automatic test equipment (ATE) software application 180 can be included on the computer 100 containing at least the files 140 and the download application 150. The ATE software application 180 is configured to transmit a request for a waveform to the download application 150, which retrieves the file 140 containing the requested waveform, checks the licensing key, configures the signal generator using the signal generator settings and downloads the waveform to the signal generator 170. The signal generator 170, in turn, "plays" the waveform, to produce a signal at the output of the signal generator 170. The computer 100 containing the download application 150 can be connected directly to the signal generator 170, or as shown in FIG. 8, the computer 100 can be connected to the signal generator 170 indirectly via the Internet 500 or another data network, such as a local area network.

As shown in FIG. 9, the files 140 can be stored remotely on a different computer (computer 100A) than the computer (computer 100B) that stores the download application and ATE software. Computer 100B can be directly connected to computer 100A or indirectly connected via one or more additional computers (not shown) or via a data network (not shown). In addition, although not shown, the files 140 can be permanently stored on computer 100A and copies of the files 140 can be transferred to computer 100B that stores

the download application 150 in order to more efficiently download the waveforms to the signal generator 170.

FIG. 10 illustrates remote automatic test equipment control of the download application 150. In FIG. 10, the ATE software application 180 is located on a different computer (computer 100A) than the computer (computer 100B) that stores the download application 150 and files 140, thereby enabling remote control of the downloading of the waveforms to the signal generator 170. As with FIG. 9, computer 100B can be connected directly to computer 100A or indirectly via one or more additional computers (not shown) or via a data network (not shown).

FIG. 11 illustrates remote automatic test equipment control of the download of files 140 from multiple storage facilities to multiple download applications 150 and multiple signal generators 170. In FIG. 11, the files 140, ATE software application 180 and download application(s) 150 are all located on different computers. For example, the files 140 can be located on two or more computers 100A1 and 100A2 for redundancy or increased storage space. In addition, the ATE software application 180 can be located on a remote computer 100B in order to control multiple download applications 150 located on multiple computers 100C1, 100C2, ..., 100Cn, each being connected to one or more signal generators 170.

Each of the download applications 150 preferably has access to each of the computers 100A1 and 100A2 storing the files 140, although each download application 150 may have a dedicated computer 100A1 or 100A2. In addition, although not shown, there may be multiple ATE software applications 180 on one or more computers 100B for controlling the multiple

download applications 150 (e.g., on a one a one-to-one basis or each ATE software application 180 may control all of the download applications 150).

As will be recognized by those skilled in the art, the innovative concepts described in the present application can be modified and varied over a wide range of applications. Accordingly, the scope of patented subject matter should not be limited to any of the specific exemplary teachings discussed, but is instead defined by the following claims.